REINFORCED SOIL AMMUNITION MAGAZINE FULL SCALE TESTS

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ABSTRACT

The paper includes the description of full scale tests conducted in Israel on an innovative reinforced soil ammunition magazine, developed by Terre Armee Ltd, Israel. The tests were performed jointly by the Israeli Air Force (IAF) and the U.S. Air Force Civil Engineering Support Agency (AFCESA) in May 1990. The reinforced soil ammunition magazine was subjected to a full-scale explosion of an adjacent magazine and withstood it's effects without any damage. Several conventional weapons explosions around the structure were also performed, to check it's structural response and failure modes. Following the explosive full scale tests, detailed construction drawings of the magazine were compiled by Eytan Building Design Ltd. and the system was approved by the Israeli Air Force as an alternative solution to the standard reinforced concrete magazine.

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INTRODUCTION

The reinforced soil technology is used in civil engineering projects in different applications, mainly for retaining walls. Terre Armee Israel Ltd, a private contractor, has suggested to the Israeli Air Force (IAF) the use of the reinforced soil elements for Air Force installations. After careful consideration, including explosive tests, the IAF has used reinforced soil elements in protective walls for different installations and in open ammunition storage areas. In 1987, a prototype reinforced soil structure, composed of reinforced soil walls, reinforced concrete floor and soil covered reinforced concrete ceiling, was tested by the IAF to check the feasibility of using it in Air Force installations. The prototype withstood nearby explosion effects
successfully and the IAF started to prepare full scale test experiments on a reinforced soil structure, to be built to the specifications of a standard IAF ammunition magazine.
At this stage, AFCESA expressed an interest to participate in the full scale tests and proposed to provide all the necessary electronic measuring devices and the personnel support for the actual recordings during the tests. The full scale tests were performed in Israel in May 1990 by the IAF with the participation of AFCESA.

TEST OBJECTIVES

The 1990 full scale tests objectives were:

a. To record the structural response of the proposed reinforced soil ammunition magazine when an adjacent magazine (represented by an equivalent explosive charge) explodes and if the performance of the test structure is found satisfactory, to approve the use of the reinforced soil structure as a standard ammunition magazine for the IAF.

b. To record the structural response of the proposed reinforced soil ammunition magazine to explosions of nearby bombs located at different distances in the soil cover in front of the mid-wall sections, in order to complement the previous tests findings and enlarge the database on the reinforced soil system response to blast dynamic loadings.

c. To observe the amount and location of the test structure debris following an internal explosion.

d. To observe the effects of the different explosions on internal items such as pipes on the walls, tiles on the floor, etc.

THE REINFORCED SOIL AMMUNITION MAGAZINE

The proposed reinforced soil ammunition magazine which was built for the full scale tests had the following dimensions: length - 14.55 meters, width - 6.60 meters and height - 3.75 to 4.12 meters, as shown in figures no. 1, 2 and 3. The magazine consisted of reinforced soil walls with 1 8cm thick concrete face elements, each connected by 4 metal strips to the soil backfill,

as shown in figures no. 4 and 5, a 20cm reinforced concrete floor and a 20cm reinforced concrete roof covered with 60cm soil. The finished reinforced soil test structure is shown in figures no.6 and 7.

Figure no. 1 Test structure - plan

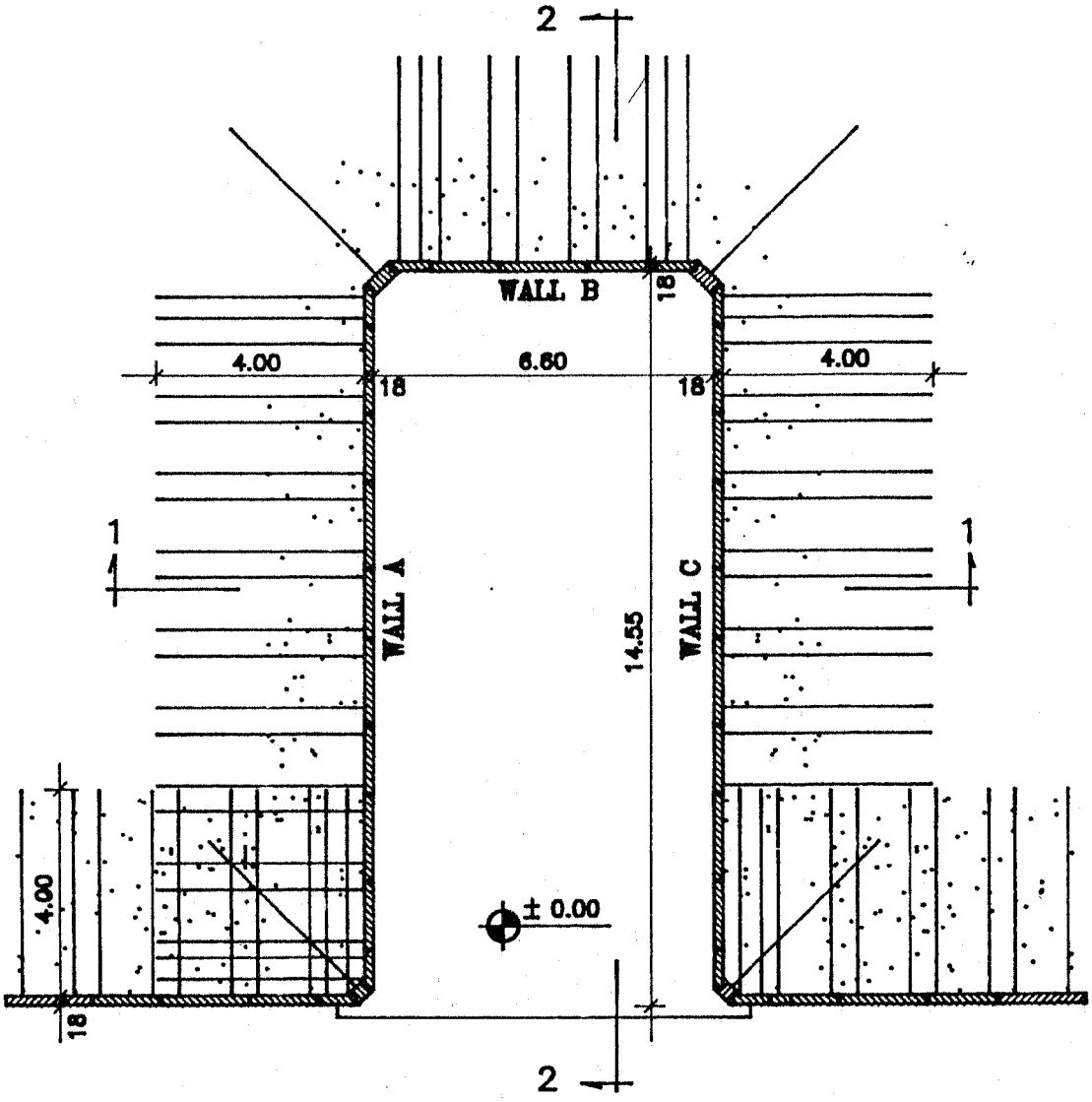

Figure no. 1 Test structure - plan

Figure no. 2 Test structure - section

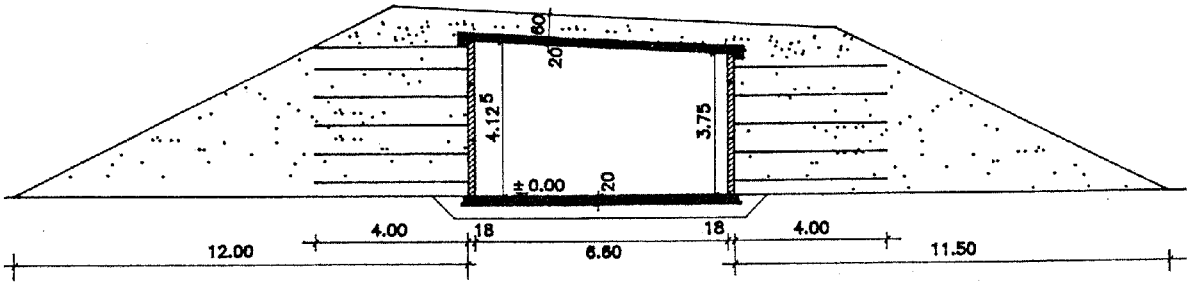

Figure no. 2 Test structure - section

Figure no. 3 Test structure - front view

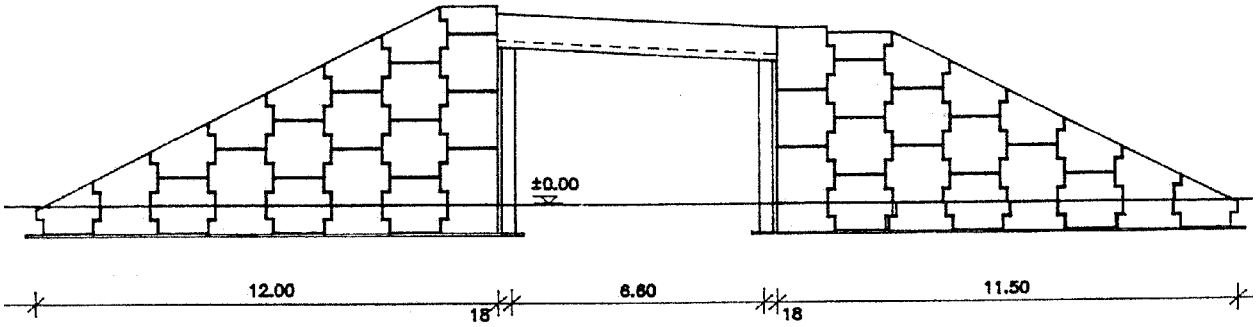

Figure no. 3 Test structure - front view

Figure no. 4 Reinforced earth concrete face element

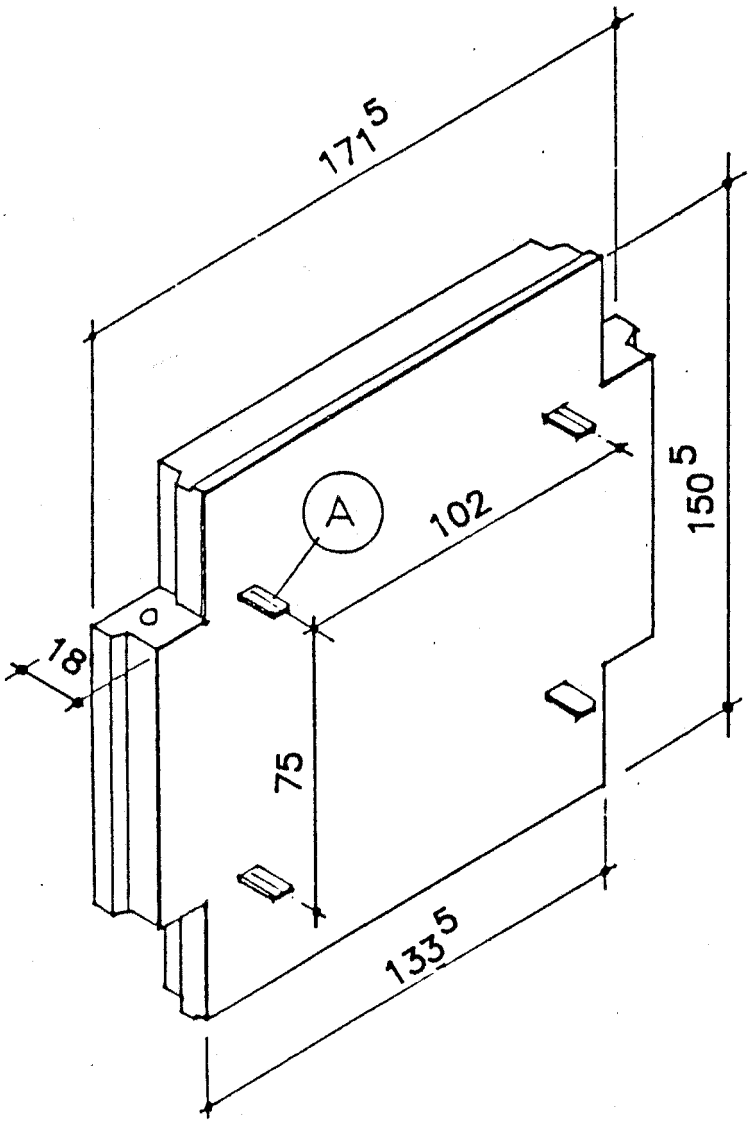

Figure no. 4 Reinforced earth concrete face element

Figure no. 5 Reinforced earth concrete face elements connections for walls A, B, C

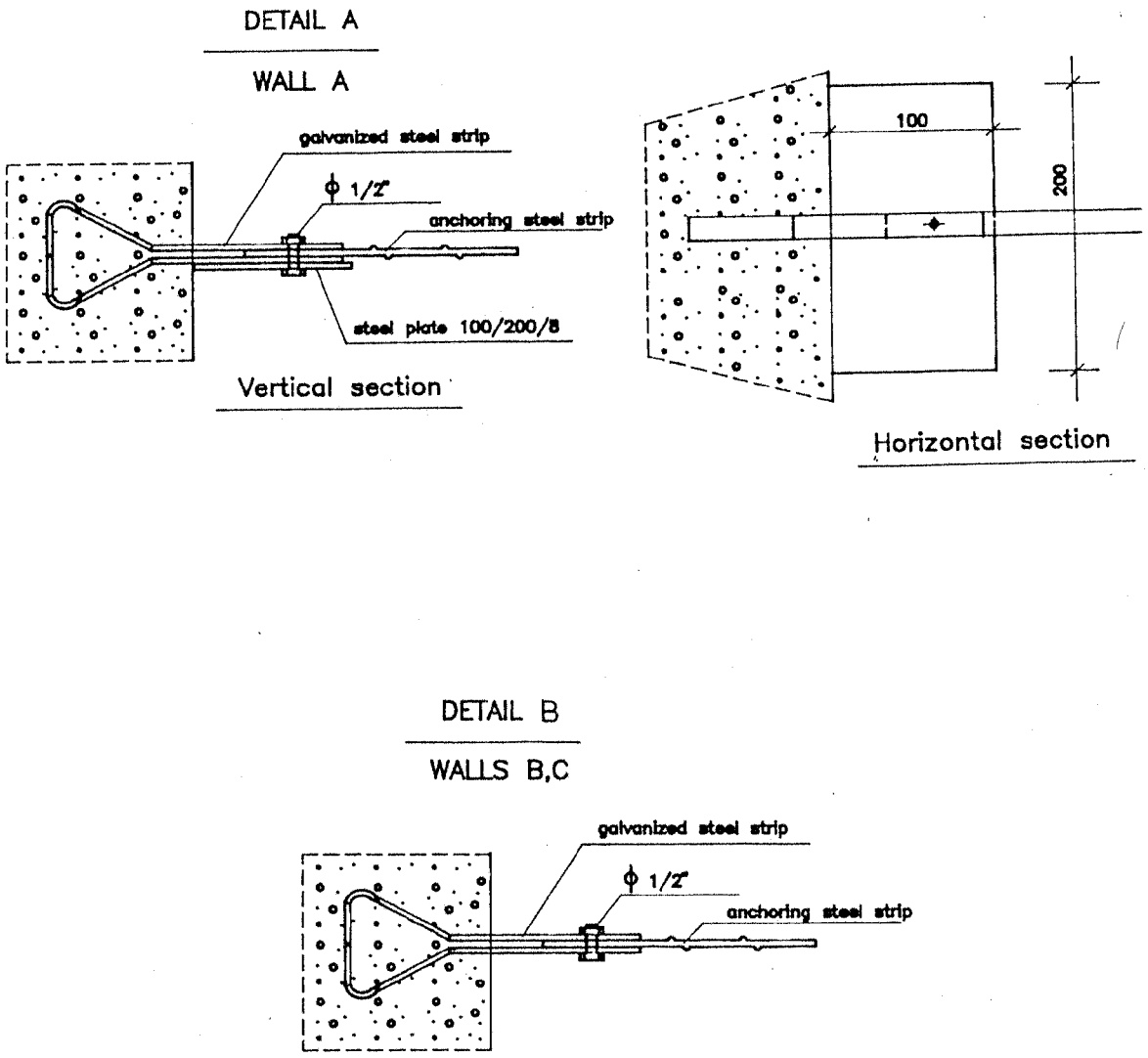

Figure no. 5 Reinforced earth concrete face elements connections for walls A, B, C

Figure no. 6 The soil covered test structure

Figure no. 6 The soil covered test structure

Figure no. 7 The finished test structure - internal view

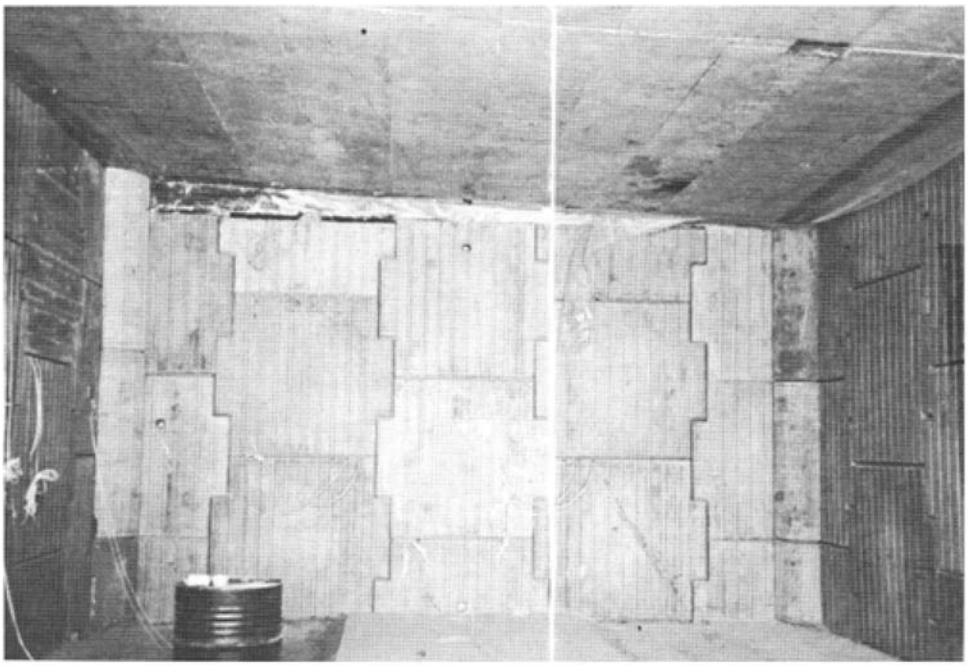

Figure no. 7 The finished test structure - internal view

INSTRUMENTATION

In order to maximize the benefit of this test to the scientific community, detailed test instrumentation was used to measure the response of the structure to conventional weapon effects.

A total of five different gage types were used to measure data during this test. Soil interface gages were installed between the concrete wall panels and backfill soil, to determine the blast pressure on the panels at selected locations. Free field soil pressure gages were placed in the soil, to measure the blast pressure in the soil. Air blast pressure gages were used on the surface burst tests to measure blast pressure near the point of detonation and inside the shelter. Accelerometers were placed on the same wall panels that had soil interface pressure gages. Finally, strain gages were installed on selected reinforcing strips. These gages were connected to a 32 channel Pacific Instruments portable data acquisition system having a maximum sampling rate of 1 ,000,000 samples per second. High speed cameras were also used both inside and outside the shelter, to provide detailed video documentation of the test.

DESCRIPTION OF THE TESTS RESULTS

The first test was a calibration test, in which an equivalent TNT charge of 1000 kg was exploded at a distance of 21.0 meters from the test structure wall. No visible displacements of the structure occurred and the electronic instrumentation worked satisfactory.

The main full scale explosive test was performed on the 14th May 1990; the explosive charge consisted of an equivalent 10 tons TNT and was activated at a distance of 28.5 meters from the test structure wall.

The visual findings after the test were:

a. The structure had no internal visible displacements, including the wall facing the explosion.

b. Small displacements of top elements of the 'wing' retaining wall closest to the explosion were observed.

c. Thin cracks appeared between the tiles on the floor.

d. No visible displacements were observed on pipes located on the end wall.

The test structure withstood the explosion effects very satisfactory with no visible damage.

Four additional conventional bombs explosions were performed at different distances from the structure's walls in which light, medium, heavy and catastrophic damages were expected. The tests results were as predicted; the structural damages to the reinforced soil walls were very localized and

even the breaching of the wall occurred by failure of two wall panels while a few cubic meters of soil spilled inside the structure. Although there was a local failure in the wall closest to the bomb, the structural stability of the magazine was still very good.

The last test consisted of the explosion of 1.6 tons TNT equivalent charge inside the magazine; the roof debris spread around in an area up to 30 meters radius, while some wall concrete face debris were found up to 40 meters from the structure.

CONCLUSIONS

The tests were successful and all the goals were achieved. The main conclusion is that the proposed reinforced soil magazine withstood without any damage the effects of the full scale explosion of an adjacent magazine.

The proposed reinforced soil structure has withstood without damages the effects of nearby bomb explosions, equivalent to the protection criteria required for civil defense shelters in Israel and protective structures for the IDF.

The reinforced soil structure has shown a "gradual" failure mode - as the blast loadings were increased, the wall concrete face elements showed increased displacements, absorbing the explosion energy by their movement.

The failure occurred locally and the overall structural stability was not affected.

The amount of wall debris was considerably lower for the reinforced soil structure that for a normal concrete wall structure.

The shock effects on internal pipes, tiles and other objects, estimated from observed displacements, brought us to conclude that the structure provides an adequate shock reduction for people and equipment.

SUMMARY

In view of the test results, the proposed Terre Armee reinforced soil magazine was approved as equivalent to the standard IAF ammunition magazine.

In view of the test results, it was recommended to consider the Terre Armee reinforced soil technology for use in protective military structures as well as civil defense shelters.

As the reinforced soil structure technology showed great potential, it was recommended to continue the research and development effort, until finalizing detailed designs for protective structures.

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